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Proceedings of the Zonal Peer Review – 2015 Assessment of Northern and Striped Shrimp

February 17-19, 2015
St. John's, NL

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

A Zonal Peer Review Process was held in St. John's, Newfoundland and Labrador (NL) February 17-19, 2015. The purpose of the meeting was to assess Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas (SFAs) 5 and 6, and both Northern Shrimp and Striped Shrimp (*Pandalus montagui*) in SFA 4 and the Eastern and Western Assessment Zones (SFAs Nunavut, Nunavik and Davis Strait).

Meeting participants were from Fisheries and Oceans Canada (DFO) Science and Resource Management in the Newfoundland and Labrador, Central and Arctic, and National Capital Regions, Newfoundland and Labrador Provincial Department of Fisheries and Aquaculture, Aboriginal groups and organizations, academia, and the fishing industry.

This Proceedings summarizes the relevant discussions and presents the key conclusions reached at the meeting. In addition, a Science Advisory Report (SAR) and Research Documents from each region, will be published on the DFO Canadian Science Advisory Secretariat (CSAS) Website.

Compte rendu de l'examen zonal par les pairs – Évaluation de la crevette nordique et de la crevette ésope pour 2015

SOMMAIRE

Un processus d'évaluation zonale a eu lieu à St. John's (Terre-Neuve-et-Labrador) du 17 au 19 février 2015. L'objectif de cette réunion était d'évaluer la crevette nordique (*Pandalus borealis*) dans les zones de pêche de la crevette (ZPC) 5 et 6, ainsi que la crevette nordique et la crevette ésope (*Pandalus montagui*) dans la ZPC 4 et les zones d'évaluation est et ouest (ZPC du Nunavut, du Nunavik et du détroit de Davis).

Les participants à la réunion représentaient le Secteur des sciences et la Gestion des ressources des régions de Terre-Neuve-et-Labrador, du Centre et de l'Arctique et de la capitale nationale de Pêches et Océans Canada (MPO), le ministère des Pêches et de l'Aquaculture de Terre-Neuve-et-Labrador, des collectivités et organisations autochtones, le milieu universitaire et l'industrie de la pêche.

Le présent compte rendu résume les discussions pertinentes et présente les conclusions importantes tirées de la réunion. En outre, un avis scientifique et des documents de recherche de chaque région seront publiés sur le site Web du Secrétariat canadien de consultation scientifique du MPO.

INTRODUCTION

Fisheries and Oceans Canada (DFO) Science was asked by DFO Fisheries Management to provide advice on stock status and sustainable harvest levels of Northern Shrimp (*Pandalus borealis*) and Striped Shrimp (*Pandalus montagui*) for the 2015-16 fishing season in Shrimp Fishing Areas (SFAs) Davis Strait, Nunavut and Nunavik, and 4-6. The advice will be used to establish Total Allowable Catches (TACs).

DFO Science held a Zonal Peer Review Process February 17-19, 2015 in St. John's, NL. The purpose of this meeting, as described in the Terms of Reference (ToR; Appendix I) was to provide the current assessment as a basis for harvest advice. The assessment included discussion of oceanographic and ecosystem considerations, including climatic change and recent increases in shrimp predator biomass. Assessments from SFAs 4-6 and Eastern and Western Assessment Zones were presented.

Meeting participants were from Fisheries and Oceans Canada (DFO) Science and Resource Management in the Newfoundland and Labrador, Central and Arctic, and National Capital Regions, Newfoundland and Labrador Provincial Department of Fisheries and Aquaculture, Aboriginal groups and organizations, academia, and the fishing industry.

After a round of introductions, a brief introduction to the meeting was provided, and the chair reviewed the agenda (Appendix III). The meeting began with presentations on environmental conditions, shrimp population dynamics, and ecosystem factors. This was followed by the assessment of shrimp beginning with SFA 6, SFA 5, SFA 4 and then the Eastern and Western Assessment Zones.

WORKING PAPER ABSTRACTS AND DISCUSSION SUMMARIES

BIOLOGICAL AND PHYSICAL OCEANOGRAPHY OVERVIEW

Authors: E. Colbourne, P. Pepin, and G. Maillet

Presenter: G. Maillet

Abstract

The North Atlantic Oscillation (NAO) Index, a measure of the direction and intensity of the winter wind field patterns over the North Atlantic, returned to a positive phase in 2014. The positive phase is normally associated with strong arctic air outflow in the northwest Atlantic during the winter months. Sea ice extent increased substantially during winter 2014 with the first positive anomaly (higher-than-normal extent) observed in 16 years. Although sea-surface temperatures (SST) based on infrared satellite imagery remain above normal in most areas across the Newfoundland and Labrador Shelves in 2014, near surface measurements have declined subsequently from record-high values observed in 2010. The cold-intermediate layer (CIL; volume of < 0°C) in 2014 was at its highest level since the early 1990s on the northeast and Labrador Shelf during summer. Bottom water temperatures collected during the fall multi-species (Divs. 2J3KL) and summer (Div. 0B, 2G) surveys in 2014 showed a substantial extent of CIL water compared to previous years. Information on catch rates in relation to bottom water temperatures indicates that 2-4°C represents a significant portion of the thermal habitat for Northern Shrimp. The shrimp thermal habitat in Div. 2J and 3K has remained above the reference mean since 1995 but has returned to near normal in 2014 after record highs documented in the later part of the 2000s.

The magnitude of the spring bloom derived from ocean colour imagery was well below normal in 2014 across the northwest Atlantic. In general, timing indices indicated delayed and shorter surface blooms in 2014. The abundance of key functional zooplankton taxa based on seasonal oceanographic surveys has remained relatively stable through time (1999-2013). Trends in zooplankton biomass indicate reciprocal transition of small (< 1 mm; mesozooplankton) and large (> 1 mm; macrozooplankton) size fractions during the mid-point in the time series. The biomass of mesozooplankton remains well-below normal while macrozooplankton has returned to near-normal in 2014 over the Newfoundland and Labrador Shelf. The composite continuous plankton recorder (CPR) trophic index, incorporating key phyto- and zooplankton taxa, was at near-normal levels in recent years (2012-13).

The extent of the CIL waters (CIL, < 0°C) is generally regarded as a robust index of ocean climate conditions off the eastern Canadian continental shelf. The CIL volume anomaly off the northeastern Newfoundland Shelf during fall has been below the long term (1981-2010) mean during the past 19 years, but increased in 2014 for the first time since 1994. Above normal extents of the CIL were pervasive throughout the mid-1980s and early 1990s and may be associated with later spawning and smaller sizes of capelin (Nakashima 1996).

Time series were presented in composite anomalies in zooplankton biomass of small (< 1 mm) and large (> 1 mm) size fractions from Div. 2J to Divs. 3LNO. The small size fraction would typically consist of small copepods, large ciliates, invertebrate larvae, and chain-forming diatoms along with larger dinoflagellates. The larger size fraction would typically consist of calanoid copepods (*Calanus spp.*), euphausiids, amphipods, mysids, and larger invertebrate larvae along with gelatinous (e.g. salps, jellies) forms. Biomass of small fraction peaked in 2002-06 but declined in 2007 and has remained below normal through to 2014. The reciprocal pattern was evident in the large size fraction with lower biomass in the first-part of the time series but transitioning to higher biomass in 2007 and remained relatively high through 2012. The biomass of the large size fraction has returned to near normal conditions in 2013-14. Increased biomass of the large size fraction of zooplankton may confer advantages to feeding in adult capelin due to the higher energetic content compared to smaller plankton. Peaks in the biomass of the large size fraction occurred in 2007 and 2011 which coincided with peaks in standardized recruitment indices of capelin (DFO 2013).

Summary

- Increase winter arctic air outflow (+NAO) with below normal winter air temperatures and above normal sea ice.
- Annual SST was above normal in 2014 but varied seasonally with cool winter/spring conditions, in contrast to record highs observed in some areas during summer.
- A sharp decrease in shelf water column temperatures (increase CIL) on NL Shelf.
- Temperature conditions in NAFO Divs. 0B & 2G were variable over past 10 years with no distinct trends.
- Bottom temperatures (2J3K) experienced a decreasing trend over past 3 years after a record high observed in 2011.
- Shrimp Thermal Habitat Index (2J3K) decreased to near normal values in 2014.
- Ocean colour metrics indicate reduced magnitude, duration, and associated delay in the timing of the production cycle in 2014.

- Zooplankton abundance of key functional taxa based on dedicated seasonal surveys along standard transects have remained relatively stable throughout the time series (awaiting 2014 results).
- Mesozooplankton (< 1 mm size class) biomass remains well-below normal over the Newfoundland and Labrador Shelf in 2014.
- Macrozooplankton (> 1 mm size class) biomass returned to near-normal in 2014 after several years of above average levels.
- The composite CPR trophic index, incorporating both 1° and 2° trophic levels was at near-normal levels in recent years (2012-13).

Discussion

Participants from both industry and DFO were interested in whether temperature trends impact biomass or simply distribution of existing biomass. However, research to date cannot adequately answer this question. It is important to note that the current cooling is a short term trend related to the NAO; it represents fine scale variability within a long term trend of consistent warming. This and previous research from DFO indicate that there is reduced thermal habitat for shrimp in the current climate, and projections suggest that this decline will continue.

A representative from DFO Science recommended caution when considering larval decapod biomass of Div. 3L; positive anomalies greater than one standard deviation have not been seen since the early 1990s. Despite recent positive anomalies, conditions remain poor when compared to the early time series. It may also be important to note that the positive anomalies recorded in the 1990s relate to colder than normal years, whereas recent positive anomalies occurred during warm years. If this information is examined beside data on Snow Crab biomass, we may find that the recent larval biomass increases reflect crab populations instead of shrimp. DFO is currently developing methods to achieve finer taxonomic resolution on larval biomass surveys, so this type of information may be available during future assessments.

SPATIAL ASPECTS OF SHRIMP POPULATION DYNAMICS

Author and Presenter: G. Evans

Abstract

This presentation reports conclusions from a DFO meeting on spatial distribution and transport of shrimp that took place in August, 2014. There was some interest in the possibility that the whole Labrador-Newfoundland (LN) shelf shrimp population might be a single unit. There was also interest in thinking about the effects of the Labrador Current on shrimp.

It is important to note that "unit" is a dangerous word, meaning different things to different people or even to the same person in different contexts. It is especially dangerous when it means one thing when justifying it and a different thing when applying it.

Summary

- Is the LN shelf a unit in the sense that it can be understood and managed just on the basis of quantities integrated over the whole shelf? **NO**.
- Is one part of the shelf a unit in the sense that it can be understood and managed without considering adjacent parts and exchanges? **NO**.

- Considering the genetics studies that stimulated the original interest: Is the LN shelf a unit in the sense that transfer from one place to another must be at least as large as one shrimp per ten million per year? **YES**.

In terms of management 'units', i.e. SFAs:

- Are there important differences among them? **YES**.
- Are there important connections among them? **YES**.
- In particular, the spawning stock *for* an SFA (i.e. the shrimp that spawned the shrimp that were caught in the SFA) was probably not the spawning stock *in* the SFA, i.e. the shrimp that spawned there.
- Can we measure and understand the connections? **NO**.
- Does how one SFA is managed have implications for the harvest sustainable in another? **Very likely**.

What is understood about the flow of the Labrador Current and the duration of the pelagic stage of shrimp larvae makes it natural to consider that many shrimp caught in one SFA were spawned as larvae in an upstream SFA. It is difficult to understand how any larvae are retained and what determines the retained fraction.

Discussion

The Labrador Current may play a major role on the transport of larvae. In the larval period, an entity can be carried well beyond the boundaries of SFAs. Based on the current dynamics alone, it is incredible that the larvae manage to settle anywhere. Recent data suggests that spawning biomass upstream correlates with recruitment lag downstream.

ECOSYSTEM CONSIDERATIONS

Author: M. Koen-Alonso, G. Evans, N., Wells, P. Pepin, J. Mercer, D. Holloway

Presenter: M. Koen-Alonso

Abstract

This presentation describes changes in the fish community, exploration of factors affecting Northern Shrimp production, and trends in shrimp predation mortality in the Newfoundland and Labrador Shelves (NAFO Divs. 2J3KL, and 2H, whenever possible).

Trends in the fish community

The overall trajectory and structure of the fish community was described on the basis of the research vessel (RV) fall survey biomass index, and considered seven fish functional groups defined on general fish size and food habits. These fish functional groups were small, medium and large benthivores, piscivores, plank-piscivores, planktivores, and shellfish. The shellfish functional group only contains commercial species like *Pandalus* shrimp and Snow Crab, and it only started to be systematically recorded in surveys after the replacement of the Engels for the Campelen gear in the mid-1990s. Conversion factors between Engels and Campelen are only available for a small suite of commercial groundfish species.

During the late 1980s and early 1990s, most of the fish community in NAFO Divs. 2J3KL collapsed. The community changed from a groundfish to a shellfish-dominated structure. Shellfish (mostly shrimp) became the dominant functional group in this marine community from

the mid-1990s to the mid-2000s. No major changes in community structure were evident during this period.

Between the mid-2000s and mid 2010s the community transitioned back to a finfish-dominated structure, and traditionally dominant groundfish species began to show positive trends. Although these increases are important (2-fold increase in total fish biomass, and 3-fold increase in total finfish biomass since 1995), current levels are still well below pre-collapse figures. Exploratory analyses suggest current overall biomass to be somewhere between 1/3 and 1/2 of pre-collapse levels. Shellfish, which had reached its peak biomass in the mid-2000s, declined significantly. The biomass levels observed in 2013-14 are the lowest in the time series (started in 1995).

Although RV survey data for NAFO Div. 2H is more limited, it also indicates that groundfish components are also showing positive trends in this region. However, these trends appear weaker than in the southern area, and are mainly driven by plank-piscivores (e.g. redfish and Arctic Cod) and large benthivores (e.g. American Plaice). The overall biomass increase of finfishes seems to be less than a 1-fold increase in this region since the mid-1990s, while shellfish biomass shows important year-to-year variability, but no obvious trend over time.

Exploration of drivers and spatial scales of shrimp production

Changes in shrimp productivity were investigated in terms of spatial scales and potential driving factors. Shrimp productivity was characterized on the basis of the per-capita production rate (P) estimated from the shrimp RV Fall survey total biomass index (B) and nominal annual shrimp catches (C_t) as $P_t=(B_t+C_t-B_{t-1})/B_{t-1}$. The candidate factors considered as potential drivers of shrimp production were shrimp stock size, fishing, environmental conditions, and predation. The indices used as proxies for the trajectories of these factors were the total shrimp RV Fall Biomass index (B) and the "leftover" shrimp biomass index ($LB_t=B_{t-1}-C_t$) for stock size, the exploitation fraction for fishing ($F_t=C_t/B_{t-1}$, where C_t is the annual nominal catch of shrimp), the composite environmental index (ENV) (Colbourne et al. 2010, 2014) for the state of the climate system, and the total RV fall biomass of piscivore, plank-piscivore, medium and large benthivore fish functional groups for predation.

The relationships between individual candidate drivers and shrimp production, as well as their trends and coherence over time were explored using non-parametric correlations (Spearman correlation coefficient *Rho*). The driver-production relationships were also considered at different time lags (1-5). The impact of drivers on a population's biological/ecological rates is unlikely to be instantaneous (it is mediated by changes in population state), and hence, the correlation between a driver and a rate would be expected to peak when the time lag that best match the actual biological/ecological mechanism underlying the relationship is considered.

All indices were calculated at different levels of spatial aggregation (Large-scale: Divs. 2J3KL, 2J3K, 3KL, and small-scale: Div. 2J, 3K, 3L), and correlation analyses were performed considered different combination of scales for both shrimp production and candidate drivers:

- large-scale driver and large-scale target area;
- large-scale driver and small-scale target area, and
- small-scale driver and small-scale target area. The only exception was ENV which is only available for the large scale of the NL shelves.

Per capita shrimp production rate showed an overall declining trend in Divs. 2J3KL; this declining trend is more evident in the southern areas (3KL). Fishing, predation and environmental forces showed detectable relationships with shrimp production. Fishing has significant negative effects on shrimp production; these effects appear with lags 2-4 and are more evident at large scales of aggregation. The warming trend in environmental conditions had

a detectable negative impact on shrimp production. At least part of this signal may be associated with the timing of the phytoplankton bloom (current trend towards earlier blooms would be associated with lower shrimp production). Predation has the most consistent effect on shrimp production. The dominant negative effect appears at lag 3, but negative impacts with lags 1-2 are also common. The difference in the structure of the correlation results (different dominant significant lags) suggest that, at first glance, the effects of predation and fishing on shrimp production are not mediated by the same mechanisms (i.e. fishing does not seem to be acting simply as "just another predator").

An analysis of cumulated per capita shrimp production rates for individual NAFO Divs. 2J, 3K and 3L was also conducted. In the absence of transfer between NAFO divisions it would be expected that cumulated curves for each area should overlay on top of each other if they were equally suitable for shrimp production, while areas with higher suitability would render cumulative curves that fall above the ones from areas with lower suitability. Since Div. 3L is not a traditional/core area for shrimp, it would be expected to have a lower suitability for shrimp production. Results indicate much higher per capita production rates in 3L than in the northern divisions. This suggests that there is an export of production from northern to southern areas, where production in Div. 3L appears to be significantly subsidized by upstream areas. Therefore SFA 6 and SFA7 (Divs. 2J3KL) would not constitute independent stock. This does not necessarily mean that there is a homogenous population in the entire area, but an entire region where there is at least sufficient connectivity among components so that impacts in some sub-areas would be expected to have measurable effects outside of them.

Estimation of food consumption by the fish community

Total annual food consumption by the fish community was delineated using a suite of models based on estimating food requirements and/or average consumption rates for different taxa. These approaches were chosen based on generality, ease of application, and low data demands, so that they could be applicable to all (or most) species in the RV survey. They were not fine-tuned for specific species and/or conditions. This analysis was intended to produce an envelope for the order of magnitude of food consumption by the entire fish community. Key assumptions/limitations of this analysis include:

- consumers actually met their expected annual requirements;
- the estimated RV biomass was a reasonable approximation to the actual biomass (i.e. no correction for catchability was made, which implies that estimations of consumption by pelagic species like capelin would be underestimated); and
- temperature dependence of consumption rates was not included.

In NAFO Divs. 2J3KL, consumption of food by those fish functional groups that can be considered predators of shrimp (medium and large benthivores, piscivores, and plank-piscivores) has increased significantly since the mid-1990s. This total consumption reached its lowest level in the early 2000s. Current estimates are coarsely three times higher than in the early 2000s. Although total consumption by "predators" functional groups seems stable and/or increasing at a lower rate since 2010, consumption of shrimp peaked in 2011-12 and declined afterwards. This decline was associated to a shift of consumption towards alternative prey, mainly capelin. Notwithstanding the decline in shrimp consumption after 2011-12, current consumption levels are still approximately twice as high as the ones estimated during the mid-1990s.

In NAFO Div. 2H, total biomass of "predators" fish functional groups, and hence its associated food consumption, has increased since the mid- to late 1990s. However, this increase is not as significant as observed in the southern areas. Estimates of shrimp consumption in 2010-14 are

highly variable, and without a clear trend. Stomach contents of key predator groundfish do not indicate a reduced role of shrimp in the diet.

Summary

- Per capita shrimp production rate shows an overall declining trend in 2J3KL; this declining trend is more evident in the southern areas (3KL).
- Fishing has significant negative effects on shrimp production; these effects appear within 2-4 years and are more evident at large scales of aggregation.
- The warming trend in environmental conditions has a detectable negative impact on shrimp production. At least part of this signal may be associated with the timing of the phytoplankton bloom (current trend towards earlier blooms would be associated with lower shrimp production).
- Predation has the most consistent effect on shrimp production. The dominant negative effect appears at lag 3, but negative impacts with 1-2 year lags are also common.
- The analysis of cumulated production rates suggests that there is an export of production from northern to southern areas.
- Results suggest that SFA 6 and SFA 7 (2J3KL) would not constitute independent stocks; this does not necessarily mean a homogenous population in the entire area, but an entire region where there is sufficient connectivity among components so that impacts in some sub-areas would be expected to have measurable effects outside of them.

Discussion

For this study, production was calculated as the difference in biomass between two consecutive years, after accounting for the fisheries removals. A representative pointed out that this means that a decrease in survival and a decrease in egg production will appear the same.

The analysis above shows that stock size does not correlate with changes in production, however fishing effort does correlate with changes in production. This may be a meaningless correlation, or an indication that fishing differentially targets the spawning stock. Northern Shrimp are protandrous hermaphrodites, transitioning from small, reproducing males to large, reproducing females at year three or four. Due to this life history, it is possible that fishing uniquely impacts spawning stock, which is composed of larger, female individuals.

Production appears to be much higher in 3L, possibly due to drift from the northern zones. If we examine the 3L data in isolation, they suggest much higher per capita production in this area, which may be due to different growth rates and life history characteristics in the local stock. However, several factors support the more parsimonious hypothesis that recruits are being transferred from Northern SFAs, including:

- more recent expansion of shrimp into NAFO Div. 3L;
- typically less favourable shrimp habitat in this area; and
- the delay between observed biomass increase in Northern regions and later increases in 3L biomass.

It was asked during this meeting if passive transport can be validated as a mechanism for recruit transfer, however this will require further research. A previous study on passive larval transport based on mean current flow suggests that larvae could travel as far as the mid-Atlantic

Ocean. It is clear that passive transport is a sufficient mechanism for north-south transfer of juveniles to 3L, but the mechanisms for settlement there are unknown.

Although total consumption by all predators of shrimp seems stable and/or increasing slightly since 2010, consumption of shrimp peaked in 2011-12. This is due to the decreasing role of shrimp in predators' diets in recent years. Despite the decrease since 2011, current consumption levels are much higher than those estimated in the mid-1990s.

OVERVIEW OF THE 2014 DFO NL MULTI-SPECIES SURVEY

Presenter: D. Stansbury

Abstract

- Major vessel failure resulted in sample gaps in 3N and 3O, and decreases in 2H where deep water surveys were eliminated (Table 1).
- Variability in timing (October-December) and duration spent in each zone may affect comparable catchability (Table 2).
- Wind force and direction is recorded to ensure that this doesn't alter catchability year to year or between sites.

Table 1. Allocation of the 2014 Fall Survey.

NAFO Division	Original allocation (# sets)	Reallocation after vessel failure
2H	84	66 (<750m)
2J	117	117
3K	156	156
3L	172	172
3N	70	0
3O	75	0
TOTAL	**674**	**511**

Table 2a. Timing and duration of DFO fall multi-species survey 2005-14 – Division 2H.

Survey Year	Start Date	End Date	Duration (days)
2006	05-Oct	20-Oct	15
2008	04-Oct	18-Oct	14
2010	07-Oct	23-Oct	16
2011	12-Oct	27-Oct	15
2012	07-Oct	26-Oct	19
2013	07-Oct	25-Oct	18
2014	06-Oct	13-Oct	7

Table 2b. Timing and duration of DFO fall multi-species survey 2005-14 – Division 2J.

Survey Year	Start Date	End Date	Duration (days)
2005	17-Nov	16-Dec	29
2006	20-Oct	14-Nov	25
2007	01-Nov	30-Nov	29
2008	07-Nov	07-Dec	30
2009	05-Nov	23-Nov	18
2010	21-Oct	15-Nov	25
2011	28-Oct	26-Nov	29
2012	14-Oct	24-Nov	41
2013	25-Oct	18-Nov	24
2014	18-Oct	14-Nov	27

Table 2c. Timing and duration of DFO fall multi-species survey 2005-14 – Division 3K.

Survey Year	Start Date	End Date	Duration (days)
2005	24-Nov	28-Jan	65
2006	06-Nov	21-Dec	45
2007	22-Nov	16-Dec	24
2008	11-Nov	21-Dec	40
2009	18-Nov	13-Dec	25
2010	15-Nov	17-Dec	32
2011	11-Nov	19-Dec	38
2012	12-Nov	20-Dec	38
2013	10-Nov	18-Dec	38
2014	08-Nov	06-Dec	28

Discussion

The survey in SFA 4 was conducted by the Cape Ballard from 2005 to 2011. Beginning in 2012, the Aqviq was used. In 2014, the vessel again changed and the Kinguk was used. Because vessel specifications were similar and there was no change in the survey gear or design, it was assumed that any effect of this change in the survey vessel would not be significant. However, no inter-calibration was conducted. The relative catch efficiency is assumed to be consistent because sampling protocol, including tow speed, sampling gear, and fishing time, are consistent across survey vessels. All samples are collected from stratified random survey sites.

AN ASSESSMENT OF THE NORTHERN SHRIMP (*PANDALUS BOREALIS*) RESOURCE WITHIN SFA 6

Author: K. Skanes, D. Orr, D. Sullivan, G. Evans

Presenter: K. Skanes

Summary

- Fishable biomass index declined from 421,000 t in 2011 to 216,000 t in 2013 and increased slightly to 233,000 t in 2014, the second lowest level in the time series.
- Female SSB index declined from 250,000 t in 2011 to 136,000 t in 2014, the lowest level in the time series. Due to strong downstream currents, the true SSB is unknown; female spawning stock in areas North contribute to the population in SFA 6 and the female stock in SFA 6 contribute to SFAs to the South.

- The exploitation rate index varied around 15% from 1997 to 2014/15, with the preliminary 2014/15 index at 18.3%. This estimate will increase to 22.3% if the TAC is fully taken.
- Research survey female SSB, at its lowest level in the time series, was assessed to be below the midpoint of the cautious zone within the Integrated Fisheries Management Plan (IFMP) Precautionary Approach (PA) Framework. If the 48,196 t TAC is maintained and taken in the 2015/16 season then the exploitation rate will be 20.7% and the female SSB will remain below the midpoint of the cautious zone.
- Prospects for recruitment to the fishable biomass are uncertain in the short term. Long-term prospects are poor, due to changes in the timing of phytoplankton spring bloom.
- Total annual mortality, based on survival of female shrimp, varied without trend throughout the available time series. Median annual mortality is 0.40.
- Both large and small vessel catch per unit effort (CPUE) have varied without trend, close to the long term average, since 2008/09.

Discussion

A participant suggested that length frequency data may hold potential for producing length-based models for stock assessment, similar to assessments conducted by the International Council for the Exploration of the Sea (ICES).Original concerns were that Northern and Striped Shrimp grow too fast for length-based models to be effective, however the bi-model length distribution may indicate a better model fit than previously expected. It was agreed that although the shrimp grow quite quickly, it may be possible to age them. However, the fact that shrimp transition from male to female in their third year may complicate this process. It was also suggested that rising ocean temperatures may drive growth rates to increase, and alter the P/B (production/biomass) ratio.

The footprint of the large vessel fishery changed significantly from the 2013-14 to the 2014-15 season, particularly in the northern range of this fishery. Researchers suggested that this difference is due to sea ice, and the fact that only 54% of the fishery has been reported so far for this season.

Regarding fishery removals, it was pointed out that over the last three years the TAC has been inconsistent with survey findings and recommendations. Considering current survey results as the best available information, the TAC can only remain the same if managers have adjusted the acceptable level of risk. Representatives also pointed out that 2014 yielded exceptional catch rates and suggested that this does not agree with declining biomass indices shown in the survey results. It was noted, however, that it is possible to have simultaneous biomass decline and consistent or increasing catch rates if range is also shrinking. It was highlighted throughout the meeting that catch rates and the research survey findings are not mutually exclusive.

Prospects for recruitment were discussed at length. Rising bottom temperatures, changes in spring phytoplankton blooms and increasing predation may significantly impact recruitment. It was agreed by all participants that the question of future recruitment is very important to the ecosystem and the fishery. Members of the shrimp industry were hesitant to include text in the SAR that describes recruitment prospects as "poor." One representative saw this as a large move from the last report that listed recruitment prospects as uncertain and did not feel that there is ample evidence for a statement that could have repercussions for harvesters' livelihoods. This was supported as a valid concern, however management indicated that is an issue to bring to the Northern Shrimp Advisory Committee, not the Zonal Peer Review Process. Researchers with DFO-Science emphasized that new evidence has been presented since the

last assessment (see presentations by G. Maillet and M. Koen-Alonso above) that supports a move from "uncertain" to a qualitative statement about recruitment potential within this stock.

AN ASSESSMENT OF THE NORTHERN SHRIMP (*PANDALUS BOREALIS*) RESOURCE WITHIN SFA 5

Author: K. Skanes, D. Orr, D. Sullivan, G. Evans

Presenter: K. Skanes

Summary

- Fishable biomass index increased from around 90,000 t in 1996-99 to 182,000 t in 2001. The index was around 142,000 t until 2013 when it dropped to 89,600 t, the lowest level in the time series, but has since increased to 116,000 t.
- Female SSB increased from around 30,000 t in 1996-99 to 93,600 t in 2001. The index was around 73,000 t until 2013 when it dropped to 41,500 t, the lowest level in the time series, but has since increased to 60,600 t.
- The exploitation rate index varied without trend around 16% from 1997-2013/14. If the TAC is fully taken, it will increase to 31.3% in 2014/15 due to the low fishable biomass index in 2013.
- Research survey SSB index was assessed to be in the Healthy Zone within the IFMP PA Framework. If the 20,970 t is maintained and taken in the 2015/16 season then the exploitation rate will be 18.1%.
- Prospects for recruitment to the fishable biomass are uncertain in the short term. Long term prospects are poor, due to changes in the timing of the spring phytoplankton bloom.
- Annual female total mortality oscillated without trend between 4% and 94% from 1999-2011, averaging about 40%.
- Large vessel CPUE increased from 2005/06 to 2010/11, declined in 2012/13, and has been increasing since.
- Commercial catch increased from about 15,000 t during 1997-2002 to around 23,000 t in more recent years. It is expected that the 2014/15 TAC of 20,970 t will be taken.

Discussion

The overall declining trend in biomass is not as strong in SFA 5 as in SFA 6, and the pattern of declining female biomass is not present in SFA 5. However, the biomass index for SFA 5 shows a significant decline from 2012 to 2013, with a rebound in 2014, which is very unlikely. Participants across sectors pointed to this anomaly and asked for a more in-depth interpretation.

DFO scientists agreed that the severe decline and subsequent recovery indicates the drop was not as severe as it looks. Researchers working on the survey were also surprised by the values, but analysis indicates that the surveys performed as expected and coverage was sufficient. There is a relatively high strata sampled in 2012, but that doesn't explain the results in 2013. All calculations were double checked at the strata level, and the results presented here are mathematically sound. A meeting participant pointed out that if either the decline or the recovery is false due to the protocol of random sampling, it is more likely that a crash would occur than a twofold increase. There is some agreement in the 2013 CPUE that the fishable biomass was lower during that season, and participants from management, industry and science agreed that

the signal cannot be ignored. The meeting concluded that more data is required, and this question will be revisited in future assessments.

AN ASSESSMENT OF THE NORTHERN SHRIMP (*PANDALUS BOREALIS*) RESOURCE WITHIN SFA 4

Author: K. Skanes, D. Orr, D. Sullivan, G. Evans

Presenter: K. Skanes

Summary

- Fishable biomass index peaked at 196,000 t in 2009, decreased to 144,000 t in the next year before increasing to 183,000 t in 2012. It has since declined to 134,000 t in 2014.
- Female SSB peaked at 138,000 t in 2009, decreased to 74,600 t in the next year before increasing to 104,000 t in 2012. It then decreased to 89,800 t in 2013 and 2014.
- The exploitation rate index ranged between 5.4% and 11.2% from 2005/06 to 2014/15, and the current index is at 11.2%.
- Research survey SSB index was assessed to be in the Healthy Zone, within the IFMP PA Framework.
- Prospects for recruitment to the fishable biomass are uncertain in the short term. Long term prospects are poor, due to changes in the timing of phytoplankton spring bloom.
- Annual female total mortality oscillated without trend between 36% and 79% from 1999-2010, averaging about 60%.
- Large vessel CPUE increased from 1992 to 2001, oscillated slightly above the mean until 2011/12, and has been increasing since.
- Commercial catch increased from approximately 10,000 t from 2005/06-2011/12 to 14,970 t in 2014/15. The TAC for 2014/15 has been taken.

Discussion

There has been very little change in the survey biomass since 2007, with a slight decrease in the fishable biomass. Small vessel quota has been transferred to the offshore fleet in this area.

It was noted that the length frequency distributions are very different in SFA 4, compared to SFA 5 and 6; the data shows almost no individuals below 15 mm. Shrimp harvesters agreed that northern fishing areas consistently yield larger shrimp. A meeting participant suggested that the difference is due to catchability; in SFA 5 and 6, high density of shrimp will trap small shrimp in the trawl that may have otherwise escaped through the mesh. However, this hypothesis seems unlikely, as the lack of small size classes is not consistent for Striped Shrimp caught in the same area (see below).

Exploitation rate indices utilize fishable biomass index from the previous year and catch from the current year. For this reason it is possible to project, based on proposed TACs, the exploitation rate for the following year in some other SFAs. Due to the summer timing of the Northern Shrimp Research Foundation (NSRF)-DFO survey, there is no ability to predict 2015/16 exploitation rate indices.

AN ASSESSMENT OF THE STRIPED SHRIMP (*PANDALUS MONTAGUI*) RESOURCE WITHIN SFA 4

Author: K. Skanes, D. Orr, D. Sullivan, G. Evans

Presenter: K. Skanes

Summary

- Fishable biomass index declined from 40,600 t in 2008 to 14,300 t in 2011 then increased to a peak of 45,200 t in 2013 before decreasing to 34,100 t in 2014.
- The female SSB index for Striped Shrimp in SFA 4 is unknown.
- The exploitation rate index varied between 0.7% in 2008 and 22.6% in 2011. If the bycatch limit of 4,033 t is taken in 2014/15, the exploitation rate index would be 11.8%.
- The potential exploitation rate index of 11.8%, as well as its upper confidence limit, is below the 20% maximum exploitation rate that is proposed for SFA 4 Northern Shrimp.
- Prospects for recruitment to the fishable biomass are unknown.
- Commercial catches of Striped Shrimp, mainly taken as bycatch at the Northern Fringe of SFA 4, increased from 280 t in 2008 to 4,700 t in 2012 and declined to 1,200 t in 2014. It is uncertain if the bycatch quota of 4,033 t will be taken.

Discussion

There is no CPUE data available for Striped Shrimp in SFA 5 because it is a bycatch fishery. Because the fishery is not always targeted (much of the TAC is taken as bycatch in the Northern Shrimp fishery), interpretation of catch data is limited.

Recruitment is still considered uncertain in this area; earlier analysis on recruitment prospects did not include data from this population.

Size frequencies were also discussed for this stock. Participants noticed that the distribution does not appear to match the Northern Shrimp in this area, but instead mirrors Northern Shrimp in SFA 5 (presence of small size classes <15 mm). This indicates that the lack of small individuals in the Northern Shrimp size frequencies is not due to catchability. It was further noted that sizes seem consistent between the two species; researchers expect Striped Shrimp to be smaller.

Exploitation rate indices utilize fishable biomass index from the previous year and catch from the current year. For this reason it is possible to project, based on proposed TACs, the exploitation rate for the following year in some other SFAs. Due to the summer timing of the NSRF-DFO survey, there is no ability to predict 2015/16 exploitation rate indices.

AN ASSESSMENT OF NORTHERN AND STRIPED SHRIMP RESOURCES IN THE EAZ/WAZ (SFAS NUNAVUT, NUNAVIK AND DAVIS STRAIT)

Author and Presenter: T. Siferd

Abstract

The Central and Arctic Region reorganized its assessment surveys for shrimp. The Western Assessment Zone is now to be surveyed annually in conjunction with the NSRF–DFO survey of the Eastern Assessment Zone (EAZ) beginning in 2014. In the Western Assessment Zone

(WAZ), the 2014 survey begins a new time series, not directly comparable with previous surveys because no trawl standardization between the DFO and NSRF surveys has taken place.

Eastern Assessment Zone: Northern Shrimp

Summary

- The fishable biomass index was above the long-term mean during 2009 to 2011 and declined to be below the mean during 2013 and 2014, and in 2014 was at 50,500 t. The female SSB index was above the mean during 2009 to 2012 and declined to be below the mean during 2013 and 2014, and in 2014 was at 34,000 t.
- The reported exploitation rate index has varied without trend since 2007/08 and in 2014/15 was at the long-term mean of 9.9% with 60% of the TAC taken. Based on the 2014/15 TAC of 8,250 t, the potential exploitation rate would be 16.4%.
- Recruitment prospects are uncertain.
- The *Pandalus borealis* resource is currently in the Healthy Zone well above the Upper Stock Reference.
- Total catches (directed and by-catch) of *Pandalus borealis* varied without trend at about 6,000 t for 1997 through 2014/15. Catch statistics in 2014/15 are not fully available but the TAC (8,250 t) will not be taken.

Discussion

Research surveys had difficulty finding bottom and therefore sampling in deep areas was restricted. Northern Shrimp are found more frequently in cold waters. This region experienced a peak in bottom temperature in 2010-11. A slight decline in biomass indices has been observed since 2011. All biomass indices are now below the long-term mean. It was noted that the biggest contributor to the decline is in area 2EX.

Eastern Assessment Zone: Striped Shrimp

Summary

- Biomass indices have fluctuated widely from 2011 to 2014 making interpretation difficult. The 2014 fishable biomass index was estimated to be 16,600 t. The Female SSB index was 12,700 t.
- The reported exploitation rate index has varied without trend from 2008/09 through 2014/15 averaging 8.3%. The reported exploitation rate in 2014/15 was 2.4% and the potential exploitation rate was 5.1%.
- Recruitment prospects are uncertain.
- The status of the resource within the PA framework is uncertain because of the wide fluctuations in the female SSB index. As a result, caution is advised when setting the TAC.
- The catch in 2014/15 was 401 t, 48% of the 840 t TAC.

Discussion

There is no explanation (beyond survey effect) for the 2012 boost, 2013 decline and subsequent recovery. Researchers have attempted to survey during neap tides, but conditions make it

difficult to know whether sampling protocols are accessing the true population. Concern was raised that the survey is not adequately sampling this highly energetic area.

Shifts in the biomass indices appear to be the inverse of SFA 4; participants asked whether this could be due to temperature changes driving shrimp into and out of neighboring areas. DFO representatives from EAZ/WAZ agreed with this hypothesis and suggested that it may be more accurate to consider EAZ, WAZ and SFA 4 as a single assessment zone.

The PA framework was also discussed; although this stock appears to be well inside the healthy zone, researchers raised questions about the validity and the PA threshold values. The reference points were calculated based on the first three years of the time series, however the results from two of these years are now considered to be unreliable. It was suggested that combining assessment zones and generating new reference points may be a viable solution.

Western Assessment Zone: Northern Shrimp

Summary

- In 2014, fishable biomass index was 21,700 t and female SSB index was 12,300 t.
- The exploitation rate index for 2014/15 was about 4%. The current TAC represents a potential exploitation rate of about 10%.
- Catch was 847 t in 2014/15 which is about 41% of the 2,080 t TAC.

Discussion

Similar results were found after a gear change from 2013 to 2014. This indicates that catchability may be reasonably consistent. It is likely that this stock remains in the healthy zone. However, the gear change does introduce uncertainty. Participants agreed that lack of adequate comparable data impedes interpretation of biomass status and relation to the PA framework.

Western Assessment Zone: Striped Shrimp

Summary

- In 2014, the fishable biomass index was 77,100 t and female SSB index was 38,900 t.
- The exploitation rate index for 2014/15 was about 8%.
- Catch was 5,800 t in 2014/15 of the 5,860 t TAC.

Discussion

Shrimp harvester representatives stated that the TAC for Striped Shrimp in the WAZ was set too low for a number of reasons (including low exploitation rate). Researchers with DFO explained that the relatively low harvest limit reflects science advice and managers' decisions to start the fishery at a low exploitation rate until a reliable time series could be assembled to more accurately understand biomass. The recent change in sampling gear effectively turns back the clock on this survey; researchers from this region strongly recommended maintaining a cautious TAC until more data is collected.

GENERAL DISCUSSION

A lot of focus was given to the findings on increasing predation rates as well as unfavorable climactic conditions and how this relates to the fishery. Many participants felt that this was an important factor, but remained unclear on how to apply new information on predation rates to the current management system.

Shrimp harvesters raised doubt that a lowered TAC would produce measurable benefits to the stock, due to current warming and increasing predation. Current fishery removals account for a small fraction of overall removals when compared directly to predation. However, fishing mortality may have a significant effect on the portion of the shrimp population that is surplus to predator needs. Fishing mortality may determine whether the difference between production gains and predation losses is positive or negative, and whether the stock increases or decreases. DFO-Science emphasized that this process is meant to be a platform for ecosystem based management and that consideration should extend beyond single species analyses.

Participants generally agreed that the best available data suggests that shrimp populations are currently in decline, perhaps back to historically "normal" levels in SFA 5 following a "bloom" period of high shrimp biomass between 2001 and 2012. The population cannot be expected to continue at the same level through increasing predation and climatic changes if fishery removals also remain constant.

Harvesters argued that the discussion of management was too limited in this forum, and that it is a question of managing both fisheries and communities through a changing climate. Effective management of interconnected stocks (e.g. shrimp and groundfish) presents a challenge to harvesters, who are required to transition between fisheries or to accept reductions in one harvest to bolster another stock.

DFO-Science representatives agreed that these points are valid and extremely important. The shift to ecosystem based management has been slow, but there is now a need for a broader framework to discuss what the harvest of shrimp means for capelin, for cod, etc. DFO-Science is working on establishing multispecies models that may contribute to future assessments.

Recruitment and renewal were also discussed throughout this meeting, including the question of larval connectivity between SFAs. It was proposed several times that SFA 4 and the EAZ/WAZ should be considered as a single unit for shrimp stock assessment. This would also necessitate the calculation of new PA framework reference points. Current reference points for the WAZ are not considered reliable due to recent gear changes in the research survey.

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APPENDIX I: TERMS OF REFERENCE

2015 ASSESSMENT OF NORTHERN AND STRIPED SHRIMP

Zonal Peer Review - Newfoundland and Labrador, and Central and Arctic Regions
February 17-19, 2015[1]
St. John's, NL

Chairperson: Karen Dwyer, Aquatic Resources, Science Branch, NL Region

Context

The status of Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas (SFAs) 4 to 6 (NAFO Divisions 2G to 3K) was assessed on a biennial basis through 2012. The status of Striped Shrimp (*P. montagui*) in SFA 4 was first assessed in January 2014.

The status of Northern Shrimp and Striped Shrimp in SFAs Davis Strait, Nunavut and Nunavik corresponding to the Eastern and Western Assessment Zones (EAZ/WAZ) were assessed on a biennial basis through 2012.

A Zonal Advisory Process was held in February 2013 and the assessment was updated in February 2014.

Fisheries Management requested the current assessment as the basis for harvest advice for the 2015/16 fishing season.

Objectives

- Assessment of Northern Shrimp in SFAs 4 to 6 (NAFO Div. 2G to 3K), as well as Striped Shrimp in SFA 4.
- Assessment of Northern and Striped Shrimp in the EAZ/WAZ.

Expected Publications

- Two Science Advisory Reports
- Proceedings
- Two Research Documents

Participation

- Fisheries and Oceans Canada (DFO) (Science, and Fisheries Management)
- Newfoundland and Labrador Provincial Department of Fisheries and Aquaculture
- Government of Nunavut
- Nunavut Wildlife Management Board
- Nunavik Marine Region Wildlife Board
- Memorial University
- Fishing Industry
- Other invited experts

[1] Summary bullets for each stock will be agreed upon in plenary during the February 17-19, 2015 meeting. February 20 and 23: planned writing of the Science Advisory Reports.

APPENDIX II: AGENDA

Zonal Peer Review – 2015 Assessment of Northern and Striped Shrimp

Newfoundland & Labrador and Central & Arctic Regions

February 17-19, 2015

Hampton Inn, St. John's, NL

Tuesday, February 17, 2015

Topic	Presenter
Welcoming/Opening	K. Dwyer (Chair)
Presentation: Aims of the meeting	G. Evans
Presentation: Biological and Physical Oceanography Overview	G. Maillet
Presentation: Spatial Aspects of Shrimp Population Dynamics	G. Evans
Presentation: Ecosystem Considerations	M. Koen-Alonso
Presentation: Overview of the 2014 Fall Multi-Species Survey	D. Stansbury
Presentation: Assessment of SFA 6 Northern Shrimp	K. Skanes
Drafting of SAR bullets for SFA 6	All

Wednesday, February 18, 2015

Topic	Presenter
Presentation: Assessment of SFA 5 Northern Shrimp	K. Skanes
Drafting of SAR bullets for SFA 5	All
Presentation: Assessment of SFA 4 Northern & Striped Shrimp	K. Skanes
Drafting of SAR bullets for SFA 4	All

Thursday, February 19, 2015

Topic	Presenter
Presentation: Assessment of Northern & Striped Shrimp in the EAZ/WAZ	T. Siferd
Drafting of SAR bullets for EAZ/WAZ	All
Discussion	All
Summary Bullets and SARS	All
Conclusions	All
Closing/Next Steps	All

Agenda remains fluid – Breaks to be determined as meeting progresses.

APPENDIX III: LIST OF PARTICIPANTS

Name	Affiliation
Derek Butler	Association of Seafood Producers
Silas Kpolugbo	Baffin Fisheries Coalition
Bruce Chapman	Canadian Association of Prawn Producers
Dennis Coates	Clearwater Seafoods
Leon King	DFO Area Office, Grand Falls-Windsor
Leigh Edgar (WebEx)	DFO Fisheries and Aquaculture Management, NCR
Tyler Jivan	DFO Fisheries Management, C&A
Erin Dunne	DFO Resource Management, NL
Annette Rumbolt	DFO Resource Management, NL
Earle Dawe	DFO Science, NL
Nadine Wells	DFO Science, C&A
Kathleen Martin	DFO Science, C&A
Tim Siferd	DFO Science, C&A
Jim Meade	DFO Science, CSA Office -NL
Lisa Setterington (WebEx)	DFO Science, NCR
Karen Dwyer	DFO Science, NL
Katherine Skanes	DFO Science, NL
Darren Sullivan	DFO Science, NL
Fran Mowbray	DFO Science, NL
Geoff Evans	DFO Science, NL
Mariano Koen-Alonso	DFO Science, NL
Peter Shelton	DFO Science, NL
Gary Maillet	DFO Science, NL
Don Stansbury	DFO Science, NL
Darrell Mullowney	DFO Science, NL
Dave Orr	DFO Science, NL
Guillaume Dauphin	DFO Science, NL
Dale Richards	DFO Science, CSA Office NL
Roland Hedderson	FFAW
Nelson Bussey	FFAW
Erin Carruthers	FFAW
Harvey Jarvis	FFAW
Jamie Goodyear	FFAW/ Fisher
Phil Barnes	Fogo Island Co-op
Perry Collins	Fogo Island Co-op
Bev Sheppard	Hr. Grace Shrimp Co/
Neil Greig (WebEx)	Makivik Corporation, Economic & Marine Div
Emilie Novaczek	Memorial University
Nancy Pond	Newfoundland and Labrador Provincial Department of Fisheries and Aquaculture
Tom Dooley	Newfoundland and Labrador Provincial Department of Fisheries and Aquaculture
Brian McNamara	Newfoundland Resources Ltd.
Mark Hartery	Newfoundland Resources Ltd.
Todd Broomfield (WebEx)	Nunatsiavut Government
Todd Russell	NunatuKavut Community Council
Jerry Ward	Qikiqtaaluk Corporation
Edgar Coffey	Quin-Sea Fisheries, Gulf Shrimp Ltd.
Ray Dalley	Quin-Sea Fisheries
Chris Butler	Quin-Sea Fisheries
Rendell Genge	Shrimp Fisher (4R)
Chris Rose	Shrimp harvester
Phowse Pittman	Torngat Joint Fisheries Board
Julie Whalen	Torngat Secretariat